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# (54) Anti-lock brake system with traction slip control

(57) An anti-lock brake system with traction slip control comprises a pedal-actuated, preferably auxiliary-force-assisted braking pressure generator (1) having a master cylinder (2), to which the wheel brakes (31,32,33,34) are connected via main brake lines (62,63), auxiliary-pressure hydraulic pumps (21,26), as well as wheel sensors (S1,S2,S3,S4) and electronic circuits (28) for determining the wheel rotational behaviour and for generating electric braking-pressure control signals. The latter, for the purpose of brake slip control, serve to control electromagnetically-actuatable pressure-fluid inlet valves (24,25,29,30) and outlet valves (22,23,35,36). The pistons (6,7) of the master cylinder (2) have central control valves (10,11) and the brake lines (62,63) cmmunicate with the electrically-driven pumps (21,26) via supply lines (45,46) in which non-return valves (38,39) are arranged and respective valves (86,87), through which pressure fluid can be delivered into the brake circuits (62,63) for the purpose of traction slip control. The poration of the supply line (45,46) interconnecting the pumps (21,26) and the valve (86,87) each communicates via a short-circuit line (95,96) with the main brake lines (62,63), with a pressure-relief valve (82,83) being interposed into each short-circuit lines (95,96). This permits the delivery of pressure fluid into the main brake lines (62,63) after a nominal pressure is exceeded. A pressure-fluid accumulator (76,77) is in communication with each short-circuit line (95,96) into which fluid is supplied by the pump (21,26) until attainment of the nominal pressure.

FIG.1

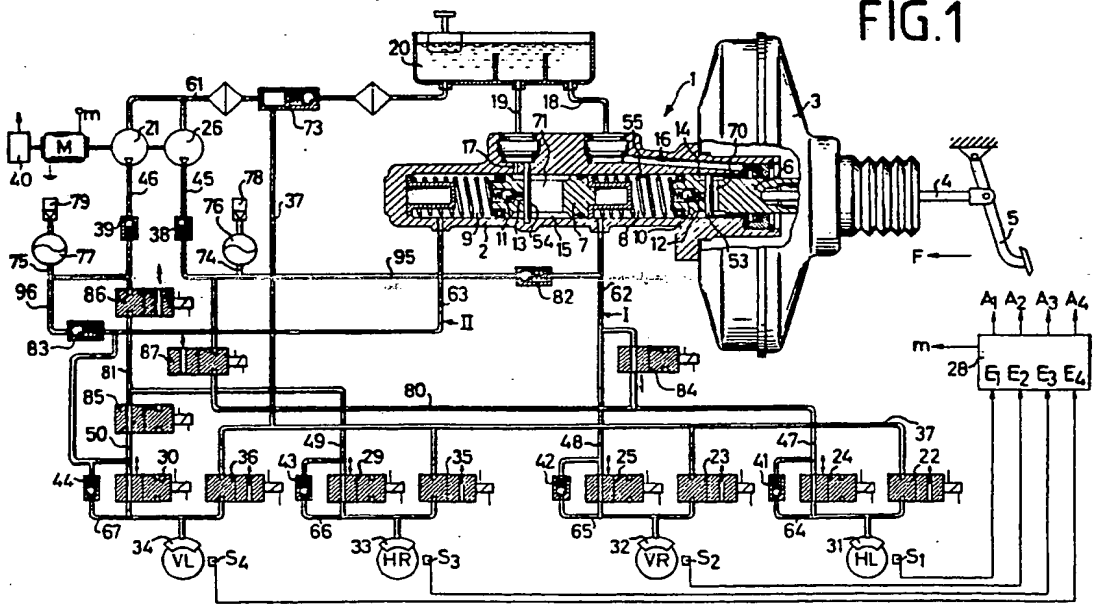


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FIG.1

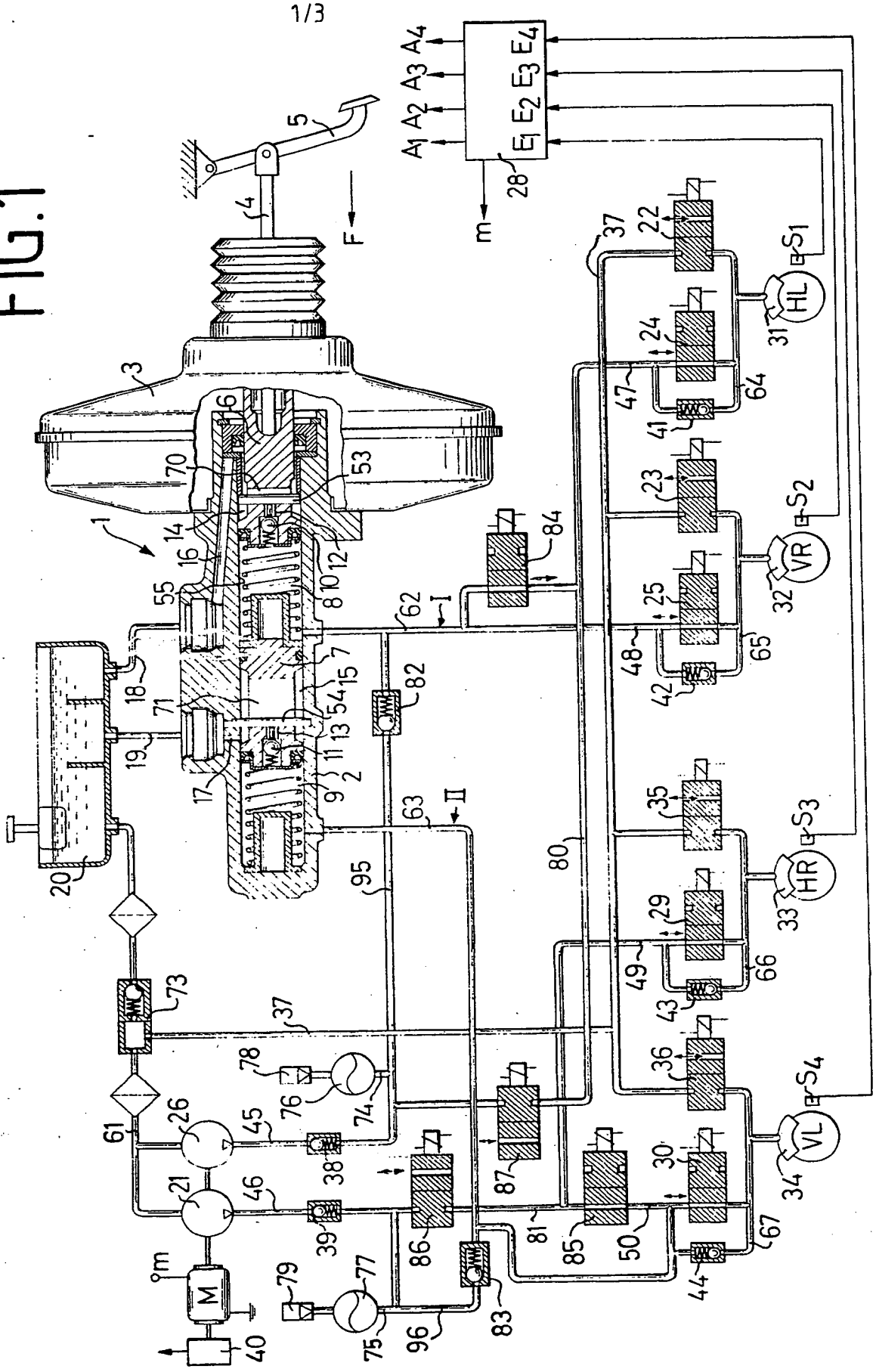


FIG.2

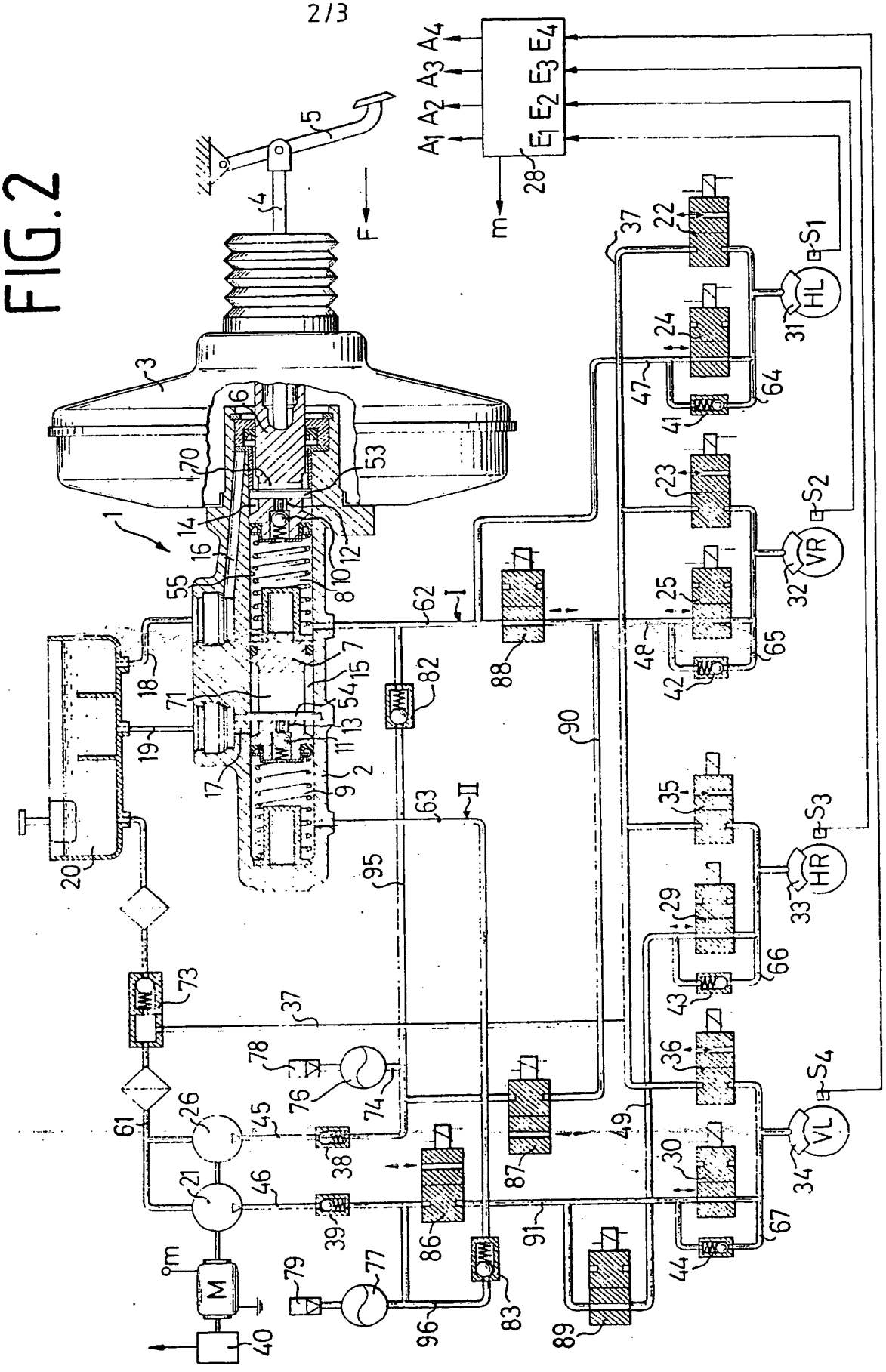
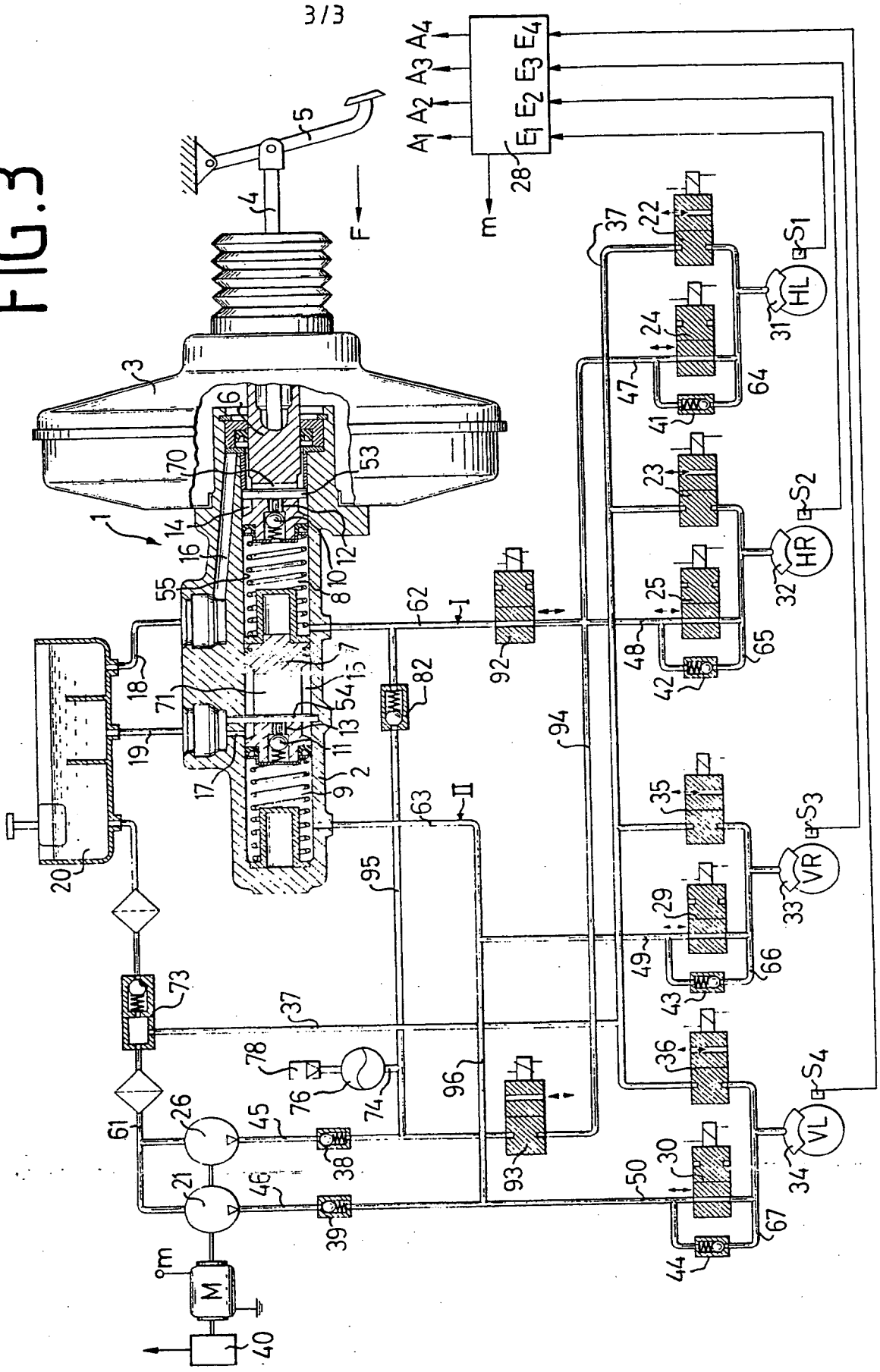


FIG.3



SPECIFICATION

## Anti-lock brake system with traction slip control

The present invention relates to an anti-lock brake system with traction slip control of the kind which comprises a pedal-actuated, preferably auxiliary-force-assisted braking pressure generator having a master cylinder, to which the wheel brakes are connected via main brake lines, auxiliary-pressure hydraulic pumps, as well as wheel sensors and electronic circuits for determining the wheel rotational behaviour and for generating electric braking-pressure control signals which, for the purpose of slip control, serve to control electromagnetically actuatable pressure-fluid inlet valves and outlet valves inserted into the pressure-fluid lines, the brake lines communicating via supply lines with the pumps, whose suction ports are connected to the supply reservoir via a suction line.

In known brake systems of this kind (German published patent applications 3040561, 3040562), a master cylinder with a hydraulic brake power booster connected upstream thereof is used as a braking pressure generator. The auxiliary-pressure supply system comprises a hydraulic pump and a hydraulic accumulator, out of which, auxiliary pressure proportional to pedal force is delivered on brake application with the aid of a control valve. On the one hand, this dynamic pressure is transmitted via the master cylinder into the static brake circuits connected to the master cylinder. On the other hand, the wheel brakes of one axle, preferably those of the rear axle, are in direct communication with the pressure chamber into which the pressure proportional to pedal force is introduced through the control valve. For the purpose of slip control, moreover, inlet valves are inserted into both the static circuits and the dynamic circuit, which valves normally assume their opened position and which, in the event of an imminent locked condition of a wheel, serve to shut off the pressure-fluid flow to the wheel brake concerned.

In addition, there are provided outlet valves which permit the discharge of pressure fluid from the wheel brake to the pressure-compensating reservoir in case of need. On commencement of slip control, the booster chamber in which the controlled pressure introduced out of the auxiliary-pressure supply system is prevailing will be connected via a so-termed main valve with the static brake circuits of the master cylinder in order to be able to replenish the quantity of pressure fluid removed through the outlet valves into the static circuits again. For safety reasons, the piston (or pistons) in the (tandem) master cylinder will be reset or fixed by means of a positioning device. The structural efforts needed for generating, storing and controlling the hydraulic auxiliary pressure, for dynamic fluid delivery into the static circuits and for safeguarding the brake functions on failure of individual circuits are considerable.

In brake systems of this kind, the control signals for the inlet valves and outlet valves are generated by means of electronic circuits, the inputs of which are connected with wheel sensors, e.g. inductive pickups for measuring data, and which thereby are able to react on a variation of the wheel rotational behaviour indicative of an imminent locked condition by successively maintaining the pressure at the wheel concerned constant, by reducing it and by re-increasing it.

It is an object of the present invention to design an anti-lock brake system with traction slip control such that the fewest valves possible are penetrated by fluid in the event of brake pressure control. Furthermore, it is desired to reset the master cylinder completely in position after each slip control action so that a maximum reserve for braking is guaranteed upon pump failure. Finally, the brake system is to enable traction slip control both in the case of diagonal brake-circuit allotment and in the case of a brake-circuit allotment front axle/rear axle for front drive and rear drive.

According to the invention there is provided an anti-lock brake system with traction slip control of the kind which comprises a pedal-actuated, preferably auxiliary-force-assisted braking pressure generator having a master cylinder, to which the wheel brakes are connected via main brake lines, auxiliary-pressure hydraulic pumps, as well as wheel sensors and electronic circuits for determining the wheel rotational behaviour and for generating electric braking-pressure control signals which, for the purpose of slip control, serve to control electromagnetically actuatable pressure-fluid inlet valves and outlet valves inserted into the pressure-fluid lines, the brake lines communicating via supply lines with the pumps, whose suction ports are connected to the supply reservoir via a suction line, characterised in that inserted into at least one of the two supply lines is a valve, through which pressure fluid can be delivered into a brake circuit for the purpose of traction slip control, the portion of the supply line interconnecting the pump and the valve communicating via a short-circuit line with one of the main brake lines, and a pressure-relief valve being interposed into the short-circuit line which permits the delivery of pressure fluid via the short-circuit line into the main brake line after a minimum pressure is exceeded but which, however, precludes pressure fluid flow in the opposite direction, a pressure-fluid accumulator being in communication with this short-circuit line, which accumulator is fed by the pump until attainment of the minimum pres-

sure.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings which, in a simplified view, partially in cross-section, partially purely schematically, display the most important component parts of three slip-controlled brake systems according to this invention.

In the embodiment illustrated in Figure 1, the brake system possesses as a braking pressure generator 1 a hydraulic unit which is substantially composed of a tandem master cylinder 2 and a vacuum booster 3 connected upstream thereof. Via a push rod 4, the pedal force F applied on a brake pedal 5 is transmitted in known fashion onto the vacuum booster 3 and from the latter, boosted by auxiliary force, onto the working pistons 6 and 7 of the tandem master cylinder 2.

In the release position of the brake shown, the pressure chambers 8,9 of the master cylinder 2 are in communication with a pressure-compensating and pressure-fluid supply reservoir 20 via open central valves 10,11, connecting channels 12,13 in the interior of the pistons 6,7 annular chambers 14,15, connecting bores 16,17 and hydraulic lines 18,19.

The two brake circuits I,II of the master cylinder 2 communicate with the wheel brakes 31,32;33,34 via electromagnetically-actuatable valves which are open in their initial position, that is to say so-called SO-valves (opened in their de-energised state) or inlet valves 24,25 and 29,30, respectively. The parallel-connected wheel brakes 31,32 and 33,34, respectively, are allocated to the diagonals, applicable to a vehicle with rear wheel drive.

The wheel brakes 31,32,33,34 are further connected to electromagnetically-actuatable outlet valves 22,23 and 35,36, respectively, so-termed SG-valves (closed in their de-energised state) which are closed in their inactive position and which, via a hydraulic return line 37, are in communication with the pressure-compensating reservoir 20, on the one hand, and, via the suction line 61, communicate with the suction sides of the pumps 21,26. These pumps are hydraulic pumps driven electromotively (motor M). The electrical connections 'm' and 'Masse' (ground) are likewise illustrated symbolically. Additionally, there is the provision of an electrically-operated function-monitoring device, i.e. monitoring circuit 40, which permits the checking of the mode of operation of the motor M.

The vehicle wheels are equipped with inductive sensors $S_1$ to $S_4$ which cooperate with a toothed disc rotating synchronously with the wheel and which generate electric signals indicative of the wheel rotational behaviour, i.e. the wheel speed and variations thereof. These signals are fed via the inputs $E_1$ to $E_4$ to an electronic signal-processing and combining circuit 28 which generates braking-pressure control signals serving to switch over temporarily the inlet and outlet valves 22,23,24,25,29,30,35,36 on detection of an imminent locked condition and thereby to keep the braking pressure constant, then to decrease it and then to re-increase it at the appropriate time. To this end, the actuating magnets of the inlet and outlet valves are driven via the outputs $A_1$ to $A_4$. The electric connecting lines between the ports $A_1$ to $A_4$ and the coils of the valves 22,23,24,25,29,30,35,36 are not illustrated for the sake of simplicity.

The circuit 28 can be realised in a known fashion by hard-wired circuits or by programmed electronic units, such as microcomputers of microcontrollers.

The switch-on signal for the start-up of the drive motor M of the hydraulic pumps 21,26 which must run during a slip control action is applied to the motor M via the connection m.

Inserted into the return line 37 or the suction line 61, is a brake-circuit protection valve which is designed as a non-return valve with intermediate reservoir and which allows replenishment supply of pressure fluid out of the pressure-fluid supply reservoir 20. Moreover, pressure accumulators 76,77 having associated pressure-monitoring switches 78,79 are connected via branch lines 74,75 to the supply lines 45,46 which interconnect the pumps 21,26 and the main brake lines 62,63, these pressure accumulators being moreover in communication with the inlet valves 24,25 and 29,30, respectively, via pressure lines 80,81 containing directional control valves 86,87 and 84,85, respectively.

The brake system operates as follows:

On brake application, the pedal force F boosted by the vacuum in the booster 3 is transmitted onto the master cylinder pistons 6,7. The central control valves 10 11 close, thus allowing braking pressure to develop in the pressure chambers 8,9 and hence in the brake circuits I,II which propagates via the main brake lines 62,63 and via the valves 24,25 and 29,30, respectively, to the wheel brakes 31,32 and 33,34, respectively, the directional valves 84,85 having assumed their opened position.

On detection of an imminent locked condition at one or more of the wheels by means of the sensors $S_1$ to $S_4$ and the circuitry 28, slip control will commence. The drive motor M of the pumps 21,26 will be switched on, whereby pressure develops in the two supply lines 45,46 which is applied on the wheel cylinders of the wheel brakes 31 to 34 via the non-return valves 38,39 and the branch lines 47,48, and 49,50, respectively, and via the inlet valves 25,26 and 29,30, respectively, on the one hand, and which acts upon the pressure chambers 8,9 of the master cylinder 2, on the other hand.

A signal from the circuitry 28 results in

changeover of the electromagnetically-actuatable inlet valves 24,25 and 29,30, respectively and thus in closure of the brake circuits I,II and the branch lines 47 to 50, respectively. Further displacement of the master cylinder pistons 6,7 in the direction of the pedal force F as well as emptying of the pressure chambers 8,9 is precluded, since the pressure fluid of the pumps 21,26 now flows via the supply lines 45,46, the opened non-return valves 38,39, the pressure-relief valves 82,83 and the main brake lines 62,63 into the pressure chambers 8,9, urges the pistons 6,7 back to their initial positions and, via the central control valves 10,11, flows off into the reservoir 20. The actual braking pressure variation in the wheel brakes 31 to 34 is determined by the inlet and outlet valves 29,30,35,36, which are furnished with further slip-controlling braking-pressure control signals via the lines $A_1$ to $A_4$.

As can be seen from the drawing, the inlet valves 24,25 and 29,30, respectively, are still protected by parallel connected non-return valves 41,42 and 43,44, respectively. In special cases, these non-return valves 41,42 permit a termination of the braking pressure control and release of the wheel brakes, respectively, since a small quantity of pressure fluid can flow back from the wheel brakes 31 to 34 into the pressure chambers 8,9, with the inlet valves 24,25 and/or 29,30 and the outlet valves 22,23 and/or 35,36 still closed, provided that the pistons 6,7 of the master cylinder 2 have been returned to their initial position and the central control valves 10,11 are in their opened condition.

Each central control valve 10,11 has a tappet which is slidably accommodated in a longitudinal bore of the piston 6,7 and whose end on the side of the pedal, abuts on a stationary bolt 53,54 which extends transversely through the piston bore 55 of the master cylinder 2 and which lifts the valve ball from its valve seat in the release position. To this end, the valve ball is held in a cage which encloses a rubber cushion or a plug of any elastic material and which can be displaced in opposition to the force of a closure spring. In the valve's position shown, the pressure fluid can flow out of the pressure chamber 8 and 9, respectively, through an annnular gap between valve ball and valve seat, through the longitudinal bore and the transverse groove into the annular chamber 14 and 15, respectively, and from here on through the channel 16 back into the pressure-fluid supply reservoir 20. As soon as the piston 6 is displaced by the pedal force F from its illustrated position in the direction of the arrow, the valve ball 56 will be seated on the valve seat 57 and will thereby close the longitudinal bore 51. Depending on the magnitude of the pedal force F, the central control valves 10,11 may adopt a breathering position, the pistons 6,7 lifting at least partially from the cross members or bolts 53,54.

When a traction slip control action is performed, the directional control valves 84,85 (opened in their de-energised state) will be closed, and the directional control valves 86,87 (closed in their de-energised state) will be switched to open so that pressure fluid is delivered out of the pressure-fluid accumulators 76,77 and/or by the simultaneously starting pumps 21,26 into the two branch lines 47,49 and permits braking of any one of the two vehicle wheels 31,33 of the driven vehicle axle (HL,HR) or even of both vehicle wheels (depending upon the actuation of the two inlet valves 24,29).

The brake system according to Figure 2 differs from that according to Figure 1 in that it is intended for use on a vehicle with front-wheel drive and, for this purpose, has two directional control valves 88,89 (opened in their de-energised state), one of them being inserted into the branch line 48 and the other into the branch line 49. On traction slip control action, these directional control valves 88,89 will be closed at once so that the pressure fluid is allowed to flow via the pressure lines 90,91 to the wheel brakes 32,34 (VR,VL) after change-over of the directional control valves 86,87.

The brake system according to Figure 3 is suitable for a vehicle with rear-wheel drive, wherein the brake circuit I feeds the wheel brakes 31,32 of the rear axle and the brake circuit II feeds the wheel brakes 33,34 of the front axle. This brake system comprises in total only one directional control valve 92 open in its de-energised state and one such valve 93 closed in its de-energised state, and, accordingly, there is provided only one accumulator 76 with pressure-monitoring switch 78. When traction slip control is effected, the pressure fluid flows out of the accumulator 76. or from the pump 26, respectively, through the opened directional control valve 93 and through the pressure line 94 to the branch lines 47,48 which, in this case, are in communication with the wheel brakes 31,32 of the rear axle. Simultaneously, the directional control valve 92 must be switched to assume its closed position.

Assigned to the pressure-fluid accumulators 76,77 are pressure-monitoring switches 78,79 which, upon attainment of a minimum or maximum pressure, issue signals to the signal-processing circuit 28 which latter, in turn, correspondingly switches on or off the motor M of the pumps 21,26.

CLAIMS

1. An anti-lock brake system with traction slip control of the kind which comprises a pedal-actuated, preferably auxiliary-force-assisted braking pressure generator having a master cylinder, to which the wheel brakes are connected via main brake lines, auxiliary-

pressure hydraulic pumps, as well as wheel sensors and electronic circuits for determining the wheel rotational behaviour and for generating electric braking-pressure control signals which, for the purpose of slip control, serve to control electromagnetically actuatable pressure-fluid inlet valves and outlet valves inserted into the pressure-fluid lines, the brake lines communicating via supply lines with the pumps, whose suction ports are connected to the supply reservoir via a suction line, characterised in that inserted into at least one of the two supply lines (45,46) is a valve (86,87,93), through which pressure fluid can be delivered into a brake circuit (I,II) for the purpose of traction slip control, the portion of the supply line (45,46) interconnecting the pump (21,26) and the valve (86,87,93) communicating via a short-circuit line (95,96) with one of the main brake lines (62,63), and a pressure-relief valve (82,83) being interposed into the short-circuit line (95,96) which permits the delivery of pressure fluid via the short-circuit line (95,96) into the main brake line (62,63) after a minimum pressure is exceeded but which, however, precludes pressure fluid flow in the opposite direction, a pressure-fluid accumulator (76,77) being in communication with this short-circuirt line (95,96), which accumulator is fed by the pump (21,26) until attainment of the minimum pressure.

2. Brake system as claimed in claim 1, characterised in that the suction line (61) of the pumps (21,26) communicates with the return line (37) interconnecting the outlet valves (22,23 and 35,36, respectively) and the supply reservoir (20).

3. Brake system as claimed in claim 1 or 2, characterised in that each brake circuit (I,II) is equipped with a pump (21 or 26) of its own, the delivery or supply lines (45,46) and, respectively, the short-circuit lines (95,96) connected thereto being in communication with the pressure chambers (8 or 9) of the master cylinder (2) or with the main brake lines (62 or 63) connected to the pressure chambers.

4. Brake system as claimed in any one of claims 1 to 3, characterised in that allocated to each supply valve (24,25 and 29,30, respectively) inserted into the branch line (47,48 and 49,50, respectively) of a brake line (62,63) is in each case one by-pass line (64 to 67) by-passing the respective supply valve, each non-return valve (41 to 44) being interposed into each by-pass line and permitting return flow of pressure fluid from the wheel cylinder into the respective brake line (62,63).

5. Brake system as claimed in any one of the preceding claims, characterised in that a central control valve (10,11) arranged in the piston (6 or 7) of the master cylinder (2) incorporates a valve member which is longitudinally slidable in a recess and which cooperates with an opening member, e.g. a tappet, in such a way that the tappet moves the valve member into its opened position when the piston (6,7) is in the release position, the tappet being supported on a stationary pivot, cross member or bolt (53,54).

6. brake system as claimed in any one of the preceding claims, characterised in that the valve member of the central control valve (10,11) is acted upon by a spring in the closing sense and cooperates with a valve seat which is fixedly arranged at the piston (6,7) of the master cylinder (2) and which is succeeded by the longitudinal bore (51) of the piston (6,7) for the purpose of pressure-fluid flow.

7. Brake system as claimed in any one of the preceding claims, characterised in that the cross member or the bolt (53,54) is stationarily supported in the wall of the master cylinder (2) and extends through a recess (70,71) in the piston (6,7).

8. Brake system as claimed in any one of the preceding claims, characterised in that a pressure-monitoring switch (78,79) is assigned to each pressure-fluid accumulator (76,77) connected to the supply line (45,46) and the short-circuit line (95,96).

9. Brake system as claimed in any one of the preceding claims, characterised in that the valves (86,87,93) interposed into the pressure lines (80,81,94) interconnecting the pressure-fluid accumulators (76,77) and the respective branch lines (47,48,49,50) of the inlet valves (24,25,29,30) are designed as two-way/two-position directional control valves actuatable electromagnetically by the signal-processing circuit (28).

10. Brake system as claimed in any one of the preceding claims, characterised in that the directional control valves (86,87,93) interposed into the pressure lines (80,81,94) are designed as valves which are closed in their de-energised condition.

11. An anti-lock brake system with traction slip control substantially as described with reference to the accompanying drawings.

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